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FOOD IRRADIATION UPDATE AND COST ANALYSIS

By
Robert T. O'Brien

November 1991

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UNITED STATES ARMY NATICK
RESEARCH, DEVELOPMENT AND ENGINEERING CENTER
NATICK, MASSACHUSETTS 01760-5000

FOOD ENGINEERING DIRECTORATE

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The objectives of this report are to provide Army leadership with information that will be useful in structuring near term decisions with respect to military support of food irradiation applications in the DoD Food Program, and identify the costs and benefits (tangible and intangible) that might be realized if irradiated foods were used in military feeding. This study is structured to illustrate the benefits of three alternatives for exploiting preservation by irradiation. In Alternative 1, data on strawberries shows that when loss due to spoilage is taken into consideration-irradiation can generate cost savings of 14% and higher. A comparison of sterilization by retort (tray can) and by irradiation (flexible institutional pouch) was made in Alternative 2-irradiation can reduce the cost of tray can items by about 2.5%, depending on the product being considered. In Alternative 3, three options for processing ground beef patties were compared to conventional preservation by freezing: a chilled product with low dose irradiation for extended shelf life-costs about $0.01 (3.6%) less than the current nonirradiated frozen product; a combination of freezing and irradiation (low dose) to extend shelf life-can provide a tactical advantage in overseas field situations, but will cost slightly more (one half of one percent) than the conventional frozen item; and irradiation (high dose) sterilization to achieve shelf stability-the cost increase per serving for hamburgers shipped to the Middle East is $0.02, $0.03 for Europe, and $0.04 for shipments in the United States.

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PREFACE

This report was prepared as part of the Department of Defense Food Research, Development, and Engineering Program, by the Food Engineering Directorate of the U.S. Army Natick Research, Development and Engineering Center (Natick).

Significant contributions were made by Dr. Irwin Taub and Mr. Christopher Rees of the Technology Acquisition Division, Food Engineering Directorate. Secretarial/administrative support was provided by Mrs. Nancy Ring of the Food Equipment and Systems Division, Food Engineering Directorate.

Food Irradiation Update and Cost Analysis

EXECUTIVE SUMMARY

Current problems associated with military feeding include the adverse effects on food quality unavoidably induced by preservation methods which must be used to kill spoilage and pathogenic microorganisms to achieve long shelf life under extreme conditions. Such is necessary to compensate for the inability to serve fresh food in many situations because chilled storage is not practical, or because transportation time to remote locations extends beyond the shelf life of many fresh foods. With regard to the food processing and food service industries (of which military food service is a part), research points out that processing, preservation and storage methods currently used are at times less hygienic than required to prevent the incidence of foodborne illness.

Given that much of the military food supply must be shelf stable, the food preservation options available today are thermostabilization, dehydration, and freeze drying. The cumulative effect of initial cooking in combination with any of these preservation methods results in some degradation in end product flavor, texture, and appearance.

Irradiation treatment at higher doses (20-71 kGy), destroys the microorganisms that are present in a particular food. The food can be stored in sealed containers at room temperature for years and not be spoiled by microorganisms. Radiation sterilized meat and poultry products have been rated superior to canned counterparts in terms of texture, appearance, and equal or better in flavor and vitamin retention.

Irradiation treatment at lower doses (0.1-10 kGy) decreases the number of spoilage microorganisms in food without sterilizing it. This process delays spoilage of highly perishable foods, such as fresh fish and shellfish. Low dose irradiation delays ripening or mold growth, and therefore extends the shelf life of some fruits and vegetables. Apples, cherries, peaches, raspberries, and tomatoes have a very high tolerance to ionizing irradiation at doses of 1 kGy. Strawberries can be irradiated at doses up to 3 kGy.

Lower doses of radiation also destroy microorganisms such as salmonella, which can cause foodborne illness. Salmonella is often present in poultry when it reaches wholesale and retail distribution outlets. Cooking to an internal temperature of 160°F kills salmonella. However, 40,000 cases of salmonellosis are reported each year, and epidemiologists estimate that the actual number of cases is closer to 2 million, due to improper handling and inadequate preparation. The medical costs and productivity losses from this disease are estimated at $1 billion annually. Problems are usually related to undercooking, storage temperature abuse, or where cooked product was handled with utensils which came in contact with infected raw foods. Better food handling practices could help solve these problems. However, low-dose radiation may be a more practical and effective solution.

Many states and countries prohibit the importation of foods suspected of contamination with live insects. During the 1981 Mediterranean fruit fly (Medfly) infestation in Florida and California, the reluctance of many buyers in other states and countries to accept produce that might be contaminated with live Medflies led to substantial economic losses on the part of growers and suppliers. Low-dose irradiation can also be used to kill insects (disinfestation) in fruits, grains and other stored foods. It is a substitute for the now banned fumigant ethylene dibromide (EDB).

A very low dose of radiation (0.05-0.15 kGy) can inhibit sprouting of vegetables such as potatoes, onions and garlic, and eliminate the trichinosis hazard in pork. The United States still has a problem with trichinosis transmitted by commercial pork. The disease is rare (about 100 cases annually), but can be serious. Irradiated pork cannot cause trichinosis even if it is eaten undercooked or raw. Irradiation would make U.S. pork more acceptable in international commerce if the product could be guaranteed free from the trichina parasite. Many countries will not accept pork from the U.S. because this guarantee cannot currently be made.

The purpose of this report is to provide Army leadership with information that will be useful in structuring near term decisions with respect to military support of food irradiation applications in the DoD Food Program. The specific objective of this effort is to identify the costs and benefits (tangible and intangible) that might be realized if irradiated foods were used in military feeding.

This study is structured to illustrate the benefits of three means for exploiting preservation by irradiation. Six food products were selected to represent these alternatives. Four are variations of products currently found in military feeding menus, and two represent added capabilities which military food service does not now possess without irradiation processing.

<u>Alternative 1</u> - Involves low-dose irradiation for longer shelf life in products that are normally preserved only by refrigeration. The products will still be held in refrigeration after irradiation. Strawberries were selected to represent this alternative, since this is a product with high customer appeal, but infrequently served in the fresh state because of its very short shelf life.

<u>Alternative 2</u> - Addresses products which are made shelf stable by high-dose irradiation, as opposed to other methods such as thermostabilization. Ambient storage will be used after the products are irradiated. This alternative covers both group feeding and individual rations. The following items were examined.

<u>Current Item</u>	<u>Irradiated Replacement</u>
Tray Can, Boned, Chicken Breast w/Gravy (Thermostabilized)	Flexible Pouch, Boned Grilled Chicken Breast
Tray Can Ham Slices w/Brine (Thermostabilized)	Flexible Pouch Baked Ham Slices
No Current Counterpart	Flexible Pouch Beef Steak
No Current Counterpart	Meal Ready-to-Eat Roast Beef Slices

Alternative 3 - Compares a frozen product to versions that are chilled and irradiated (low dose), frozen but also irradiated (low dose) to extend shelf life after the item is tempered, and a version that is irradiated (high dose) for shelf stability. This alternative was illustrated with ground beef patties, since this item is served so frequently in military and commercial operations.

Variables

For the purposes of this analysis, the cost to process, transport and store a particular food item is dependent upon one or more of the following key variables:

Processed Gross Weight/Serving

Processed Gross Volume/Serving

Residual Shelf Life When Product Reaches User

Inventory Turnover

Spoilage Rate

Irradiation Source

Irradiation Dose

Irradiation Plant Throughput

Irradiation Plant Utilization

Cost Factors

In this analysis, the costs associated with very distinct items/processes are being examined. Different cost factors come into play, depending on the item under consideration and the processing/distribution steps involved. The following are the cost factors considered pertinent to this study.

Blast Freezing Cost

Retorting Cost

Irradiation Preservation Cost

Package Material Cost

Annual Ambient Storage Cost

Annual Refrigerated Storage Cost

Annual Freezer Storage Cost

Primary Ambient Transportation Cost

Primary Temperature Controlled Transportation Cost

Supplemental Temperature Controlled Transportation Cost

Net Product Cost (actual cost after spoilage is considered)

In all the cost illustrations of this report, the cost of materials or processes is provided on an incremental basis. The analysis considers only the differences in cost between concepts, i.e., current methods vs. irradiation, and ignores costs that remain unaffected by a switch to irradiation.

In Alternative 1, low-dose irradiation to extend the shelf life of fresh strawberries was examined. It appears from the analysis of this alternative that irradiation can be of benefit in extending the shelf life of highly perishable chilled items. The potential reduced losses due to spoilage of the irradiated product can have a large effect on net cost. The example provided on strawberries shows that when loss due to spoilage is taken into consideration, irradiation can generate cost savings of 14% and higher compared to the actual cost of the conventional chilled product.

A comparison of sterilization by retort (tray can) and by irradiation (flexible institutional pouch) was made in Alternative 2. The costs associated with irradiation (irradiation, blast freezing) can be offset by reduced transportation and packaging costs. The cost of transportation from vendor to depot is reduced because the pouch packaged irradiated product weighs substantially less than the thermostabilized tray can counterpart. Most thermostabilized products for group feeding must have added liquid in the form of a gravy or sauce to promote heat transfer. This is not necessary with radiation, since the process works best at cold temperatures. The resulting savings in weight allows double the quantity of the irradiated product to be delivered per shipping container. Overall, irradiation can reduce the cost of tray can items by about 2.5%, depending on the product being considered.

For individual rations (i.e. the MRE or Meal Ready-to-Eat), the costs associated with irradiation are additional, since weight savings are not generally possible, and there is no change in packaging from the current ration to produce cost reductions. The items analyzed, irradiation protected MRE Sliced Roast Beef and MRE Beef Steak, would cost about $0.035 and $0.06 more per serving, respectively, than similar thermostabilized products.

For both group and individual rations, irradiation will allow the military to offer shelf stable items it cannot now provide, such as grilled whole chicken breast, baked ham, medium-rare roast beef, and grilled shrimp, all without added sauce or gravy. This can help dispel the notion of "casserole syndrome" that is a problem with regard to how customers currently perceive field rations.

In Alternative 3, three options for processing ground beef patties were compared to conventional preservation by freezing: a chilled product with low dose irradiation for extended shelf life; a combination of freezing

and irradiation (low dose) to extend shelf life; and irradiation (high dose) sterilization to achieve shelf stability. The chilled low-dose hamburger costs about $0.01 (3.6%) less than the current nonirradiated frozen product. The shelf life of 21-28 days can be taken advantage of in domestic shipments. However, the product does not provide a comfortable margin for shipment overseas, which usually requires 20-30 days.

The frozen irradiated (low dose) product can provide a clear tactical advantage in overseas field situations, but will cost slightly more (one half of one percent) than the conventional frozen item. This concept is designed to take advantage of the fact that if any temperature-controlled storage is available in the field, it is usually chilled and not frozen. This irradiated product is kept frozen during overseas shipments, and is allowed to temper in field reefers. This would provide 24-31 days shelf life after being off-loaded at the port, as compared to 7-10 days shelf life of a nonirradiated frozen product that is allowed to temper in field reefers. It normally takes 3-7 days in theater for shipment from port to customer. This leaves a minimum of 17 days shelf life remaining to provide logistical flexibility in field feeding situations, provided field refrigeration is available.

The shelf stable hamburger provides a clear-cut tactical advantage in field feeding situations. From a logistic point of view, field reefers do not have to be purchased, transported, leased, or maintained. The shelf stable item will cost more, since savings in transportation and storage costs do not offset cost increases for packaging to maintain shelf stability and the irradiation process. The cost increase per serving for hamburgers shipped to the Middle East is $0.02, $0.03 for Europe, and $0.04 for shipments in the United States. This item would be precooked, and would only have to be reheated for customer service. Savings associated with reduced energy and labor costs at final preparation have not been factored into this analysis. It is possible that such savings will offset the increased cost attributed to attaining shelf stability.

Food Irradiation Update and Cost Analysis

I. Introduction

In the book The Physiology of Taste (1825), one of the pioneers of gastronomy, Anthelme Brillat-Savarin, wrote that cookery techniques "derive nonetheless from the highest scientific principles."[1] Irma Rombauer's The Joy of Cooking has been expanded to include more than 100 pages on the interaction of ingredients and preparation methods. Even Julia Child has acknowledged the scientific and chemical significance of certain food preparation procedures. Suffice it to say that science has for years helped to expand the benefits we derive from new techniques in food preparation. Food preservation by irradiation is an example of one scientific technique that has the potential to significantly improve not only the wholesomeness of food products, but to increase the variety of foods that can be provided to the individual soldier in a field environment.

A request has been made by the Deputy Commanding General for Research, Development and Acquisition, Army Materiel Command, for a review of the utility that radiation preserved foods might offer the military food service system. To date, this technology has seen limited use in the United States. However, many foreign countries, including the Netherlands and Japan, have successfully produced and marketed irradiated food products. The recent decision made by the U.S. Food and Drug Administration (FDA) to allow irradiation of poultry is encouraging to proponents of food irradiation technology.

There are signs in the public sector that progress is being made. Vindicator of Florida, Inc. recently announced completion of site selection, building permit and construction contracting activities to build an irradiator for agricultural (citrus) products and packaging materials.[2] A leading trade publication recently pointed out that as long as the price of irradiated poultry is in line with current product, then the safety it provides with regard to control of salmonella is of interest to the food service industry.[3]

The purpose of this report is to provide Army leadership with information that will be useful in structuring near term decisions with respect to military support of food irradiation applications in the DoD Food Program. The specific objective of this effort is to identify the costs and benefits (tangible and intangible) that might be realized if irradiated foods were used in military feeding.

Information About Food Irradiation

-Irradiation is the use of ionizing radiation to preserve food. By temporarily dislodging electrons, ionizing radiation converts atoms and molecules to ions. These ions quickly restabilize into molecules with complete sets of paired electrons. The food does not become radioactive.

-Scientific data indicate that irradiated food as approved by the FDA is safe and nutritious.

-The U.S. Department of Agriculture estimates that the American consumer will receive approximately $2 in benefits (reduced spoilage, less foodborne illness) for each $1 spent on irradiation.[4]

-In September 1986, two tons of irradiated mangoes were sold in a Miami, Florida supermarket with FDA-approved labeling. The irradiated mangoes sold rapidly at the same or higher price than non-irradiated mangoes.[5]

-In 1984 the American Medical Association reported to Congress that food irradiation is safe, may be an important substitute for pesticides, and can control bacterial contamination in foods.

What Can Irradiation Preservation Do?

Irradiation is currently used to sterilize (completely destroy all bacteria and microorganisms) more than 50% of sterile disposable medical supplies used in the United States. This technique can be applied to foods. Irradiation treatment at higher doses (20-71 kGy), destroys the microorganisms that are present in a particular food.[6] The food can be stored in sealed containers at room temperature for years and not be spoiled by microorganisms. Radiation sterilized meat and poultry products have been rated superior to canned counterparts in terms of texture, appearance, and equal or better flavor and vitamin retention.[7]

Irradiation treatment at lower doses (0.1-10 kGy) decreases the number of spoilage microorganisms in food without sterilizing it. This process delays spoilage of highly perishable foods, such as fresh fish and shellfish. Low-dose irradiation delays ripening or delays mold growth, and therefore extends the shelf life of some fruits and vegetables. Apples, cherries, peaches, raspberries, and tomatoes have a very high tolerance to ionizing irradiation at doses of 1 kGy.[8] Strawberries can be irradiated at doses up to 3 kGy.[9]

Lower doses of radiation also destroy microorganisms such as salmonella, which can cause foodborne illness. Salmonella is often present in poultry when it reaches wholesale and retail distribution outlets. Cooking to an internal temperature of 160°F kills salmonella. However, 40,000 cases of salmonellosis are reported each year, and epidemiologists estimate that the actual number of cases is closer to 2 million, due to improper handling and inadequate preparation. The medical costs and productivity losses from this disease are estimated at $1 billion annually.[10] Problems are usually related to undercooking, storage temperature abuse, or where cooked product was handled with utensils which came in contact with infected raw foods. Better food handling practices could help solve these problems. However, low-dose radiation may be a more practical and effective solution.

Many states and countries prohibit the importation of foods suspected of contamination with live insects. During the 1981 Mediterranean fruit fly (Medfly) infestation in Florida and California, the reluctance of many buyers in other states and countries to accept produce that might be contaminated with live Medflies led to substantial economic losses on the part of growers and suppliers. Low dose irradiation can also be used to kill insects (disinfestation) in fruits, grains and other stored foods. It is a substitute for the now banned fumigant ethylene dibromide (EDB).

A very low dose of radiation (0.05-0.15 kGy) can inhibit sprouting of vegetables such as potatoes, onions and garlic, and eliminate the trichinosis hazard in pork. The United States still has a problem with trichinosis transmitted by commercial pork.[11] The disease is rare (about 100 cases annually), but can be serious.[11] Irradiated pork cannot cause trichinosis even if it is eaten undercooked or raw. Irradiation would make U.S. pork more acceptable in international commerce if the product could be guaranteed free from the trichina parasite. Many countries will not accept pork from the U.S. because this guarantee cannot currently be made.

Nutritional Studies

Low-dose irradiation treatments do not cause significant decreases in the nutritional quality of foods. In some cases, high-dose treatments cause measurable losses in some vitamins, such as thiamine in pork. These losses are similar to those by other often used processing techniques that produce a similar degree of preservation, such as canning, and therefore are not considered detrimental to a healthy diet.

How Can One Type of Treatment Do So Many Things?

Higher doses of radiation destroy the cells of living microorganisms, thus eliminating the pathogens, microorganisms or insects that invade our food supply. Lower doses alter the biochemical reactions, such as those involved in fruit ripening, and interfere with cell division, which is necessary for the reproduction of parasites and the sprouting of vegetables. Various applications of food irradiation are included in Table 1.

Currently, 36 countries around the world permit irradiation preservation of food.[12] Dose levels range from 0.02-0.15 kGy for onions in Argentina, 7 kGy for poultry in Canada, Chile, and Israel, 10 kGy for muesil-like cereal in France, 20 kGy for onions in Germany (previously East Germany), up to 30 kGy for spices in the United States. In Japan, 10,000 tons of potatoes are irradiated each year to prevent sprouting (chemical treatments to inhibit potato sprouting are illegal in Japan). Plants in the Netherlands and Belgium irradiate about 18,000 and 8,000 tons per day, respectively, of a large variety of foods. Two commercial plants in South Africa process irradiated mangoes, papayas, and vegetables.[13]

Clearances have been expanded recently in the United States and the United Kingdom. On May 2, 1990, FDA approved an amendment to the food additive regulations for irradiation of poultry to control food-borne pathogens. The approval was based in part on results of studies performed by Raltech Scientific Services. The Raltech studies were carried out with chicken that had been thermally processed to inactivate enzymes, cooled to -40°C, and irradiated in the frozen state in the absence of air at doses ranging from 45-59 kGy. The FDA found no evidence in any of these studies of adverse effects that could be attributed to the irradiation process.[14]

Table 1. Applications of Food Irradiation

Type of Food	Radiation Dose In kGy	Treatment Effect
Meat, poultry, fish, shellfish	20-71	Sterilization-room temperature storage without spoilage.
Spices and other seasonings	30	Destroys insects and microorganisms.
Meat, poultry, fish	0.1-10	Delays spoilage by reducing the number of microorganisms in the fresh product. Reduces pathogens, renders parasites harmless.
Strawberries, other fruits	1-5	Extends shelf life by delaying mold growth.
Grain, fruits	0.1-2	Kills insects or prevents them from reproducing.
Bananas, avocados, mangoes, papayas, guavas, and certain other non-citrus fruits	1	Delays ripening.
Potatoes, onions, garlic, ginger	0.05-0.15	Inhibits sprouting.

The food products approved for irradiation in the United States are shown in Table 2.

On August 5, 1990, the United Kingdom approved proposals which will permit fruit, vegetables, cereals, bulbs and tubers, spices and condiments, fish and shellfish, and fresh and frozen meat to be processed at a maximum dose of 0.5kGy.[15]

Table 2. U.S Approved Food Products for Irradiation

Food	Maximum dosage permitted	Purpose of irradiation
Pork	1kGy	Control Trichinella Spiralis
Fresh and frozen poultry products	3kGy	Control Salmonella and other bacteria
Fresh fruits and vegetables	1kGy	Inhibit growth and maturation
Wheat, rice, barley, fruit, vegetables, nuts, and other foods where infestation occurs	1kGy	Disinfestation of anthropoid pests (insects, spiders, mites)
Dry and dehydrated enzyme preparations	10kGy	Microbial disinfestation
Dry and dehydrated aromatic vegetable substances-herbs, seeds, spices, vegetable seasonings, blends of these substances, and turmeric and paprika when used as color additives	30kGy	Microbial disinfestation

II. Problem Definition

Current problems associated with military feeding include the adverse effects on food quality unavoidably induced by preservation methods which must be used to achieve long shelf life under extreme conditions. Such is necessary to compensate for the inability to serve fresh food in many situations because chilled storage is not practical, or because transportation time to remote locations extends beyond the shelf life of many fresh foods. With regard to the food processing and food service industries (of which military food service is a part), research points out that processing, preservation and storage methods currently used are at times less hygienic than required to prevent the incidence of foodborne illness.

Much of the military food supply must be shelf stable. Given this, the food preservation options available today are thermostabilization, dehydration, and freeze drying. The cumulative effect of initial cooking in combination with any of these preservation methods results in some degradation in end-product flavor, texture, and appearance.

To achieve commercial sterility, food must receive sufficient heat to inactivate both enzymes and microorganisms. To accomplish sterilization, the majority of foods must be packaged in a liquid medium (brine, sauce, gravy) to allow proper heat transfer. Furthermore, the food product (i.e. non-liquid contents) in a conventional cylindrical container must be small or thin enough in size to also allow proper heat transfer for sterilization. This simply means that thermostabilized food items in a cylindrical can must be configured as chunks, dices, or thin slices in a liquid medium. From the customers' point of view, this can lead to a "casserole syndrome", and the impression that different food products taste alike, in part because of similar texture and flavor qualities caused by the high heat processing techniques.

The tray can, due to its rectangular configuration, offers significant advantages over the typical round can. Because of its shape, a greater variety of popular foods like lasagna or whole chicken breasts can be accommodated by this container. Furthermore, also because of its shape, heat is transmitted more quickly to the geometric center of the can, as compared to a standard number 10 cylindrical can (the conventional counterpart. Consequently, commercial sterilization is achieved in approximately half the time. The institutional retort pouch (flexible package) offers most of these advantages, plus the fact the pouch is much lighter (1.3 ounces) as compared to the tray can (13.6 ounces).

For individual rations, e.g. the Meal Ready-to-Eat (MRE), the single portion of food is often thin or in small enough pieces that heat transfer is sufficient to allow sterilization without added liquid.

Shelf stability is not always required for food products used in military feeding. But, most products must still be preserved by chilled or frozen storage, specific packaging methods, added ingredients, or a combination of these. Frozen storage provides a longer shelf life than refrigeration, but also adds an extra logistic burden, is more expensive, and can adversely affect food texture. Some foods are served infrequently

despite their high customer appeal, because of a lack of enough frozen storage space, or because freezing affects end-product quality to the extent that customer appeal is somewhat reduced. The ability to serve a greater quantity of items that are preserved by refrigeration, as opposed to frozen storage, has the potential to result in higher customer acceptance ratings.

Chilled storage has its own limitations. It is more expensive than ambient storage, and extends the shelf life of fresh products to only a limited extent. Moderate doses of irradiation can extend the shelf life of refrigerated products, which reduces losses due to spoilage. It can also greatly reduce the pathogens in foods that cause foodborne illness, which increases food safety. Refrigeration alone only halts the growth of these pathogens.

III. Cost Analysis

Scope

Low-dose irradiation provides the capability to offer chilled items with extended shelf life to meet logistic requirements and reduce losses due to spoilage. Irradiation also allows (although not at current permitted dose levels) shelf stable items that retain most of the texture, color, appearance, and flavor of their fresh counterparts. The food item is sterilized for shelf stability, but not overcooked.

This study is structured to illustrate the benefits of three means for exploiting preservation by irradiation. Six food products were selected to represent these alternatives. Four are variations of products currently found in military feeding menus, and two represent added capabilities which military food service does not now possess without irradiation processing.

Alternative 1 - Involves low dose irradiation for longer shelf life in products that are normally preserved only by refrigeration. The products will still be held in refrigeration after irradiation. Strawberries were selected to represent this alternative, since this is a product with high customer appeal, but infrequently served in the fresh state because of its very short shelf life.

Alternative 2 - Addresses products which are made shelf stable by high dose irradiation, as opposed to other methods such as thermostabilization. Ambient storage will be used after the products are irradiated. This alternative covers both group feeding and individual rations. The following items will be examined.

Current Item	Irradiated Replacement
Tray Can, Boned, Chicken Breast w/Gravy (Thermostabilized)	Flexible Pouch, Boned Grilled Chicken Breast
Tray Can, Ham Slices w/Brine (Thermostabilized)	Flexible Pouch, Baked Ham Slices
No Current Counterpart	Flexible Pouch, Beef Steak
No Current Counterpart	MRE Roast Beef Slices

Alternative 3 - Compares a frozen product to versions that are chilled and irradiated (low dose), frozen but also irradiated (low dose) to extend shelf life after the item is tempered, and a version that is irradiated (high dose) for shelf stability. This alternative will be illustrated with ground beef patties, since this item is served so frequently.

Variables

For the purposes of this analysis, the cost to process, transport and store a particular food item is dependent upon one or more of the following key variables:

Processed Gross Weight/Serving

Processed Gross Volume/Serving

Residual Shelf Life When Product Reaches User

Inventory Turnover

Spoilage Rate

Irradiation Source

Irradiation Dose

Irradiation Plant Throughput

Irradiation Plant Utilization

Consumable portion gross weight and volume are related to how a product is packaged. For example, the current tray can chicken breast with gravy has a net weight of 6.5 pounds, with a drained weight of about 3 pounds. The container holds 9 servings, each about 5 ounces of chicken, plus gravy. However, 6.5 pounds of contents must be processed to yield these 9 portions. Thus, the processed portion gross weight is 11.55 ounces.

Residual shelf life and spoilage rate affect actual product cost. The shelf life which remains after the product gets through the supply distribution system is highly dependent on the spoilage rate of the product.

Inventory turnover affects the cost of storage per item. The type of irradiation source, dose level, plant utilization and throughput (amount of product processed in a specified period of time) affect the cost of irradiation.

Cost Factors

In this analysis, the costs associated with very distinct items/ processes are being examined. Different cost factors come into play, depending

on the item under consideration and the processing/distribution steps involved. The following are the cost factors considered pertinent to this study.

Blast Freezing Cost

Retorting Cost

Irradiation Preservation Cost

Package Material Cost

Annual Ambient Storage Cost

Annual Refrigerated Storage Cost

Annual Freezer Storage Cost

Primary Ambient Transportation Cost

Primary Temperature Controlled Transportation Cost

Supplemental Temperature Controlled Transportation Cost

Net Product Cost (actual cost after spoilage is considered)

The data, sources and/or calculations used to determine the value of the above cost factors, and the cost of processing operations presented in Table 3 are presented in Appendix A. Fixed and operating annual costs for irradiation are presented in Appendix B.

Table 3. Food Processing Costs

Retort	\$0.033/lb. food product
Blast Freezing	\$0.055/lb. food product

Food processing costs fluctuate depending on market forces (e.g. labor, utility, insurance costs, seasonal fluctuations, etc.). However, production throughput (amount of product processed per period of time) and plant utilization (hours of operation per period of time) can effect production cost, regardless of market conditions. Particularly with a radioisotope source, which is essentially always turned "on", utilization can be especially critical. The cost of radioactive waste disposal for Cobalt 60 has not been addressed.

Machine irradiation sources (e.g. electron beam or X-rays) can be turned off at the end of the production period, so plant utilization and throughput are not as important. Also, since machine irradiation sources do not have a continually active source of radiation present, industry experts feel the general public will consider this approach more safe than a radioisotope source. In addition, there is no radioactive waste to dispose of with machine

irradiation. However, electron beam irradiation will penetrate food to a total depth of about 1 inch in more dense items (e.g. steaks, chops, chicken breasts, and 2 inches in lighter items (vegetables). Thus, only foods in individual, thin packages or a shallow stream (grains, powder, liquid) of product can be processed by electron beam sources. On the other hand, X-rays and gamma rays can readily penetrate about 10 inches, which allows this source to be used for irradiating an entire case of food. The irradiation costs in this report are based on the use of electron beam processing where the penetration required is less than 1 inch, and Cobalt 60 processing in all other cases.

In all the cost illustrations to follow in this report, the cost of materials or processes is provided on an incremental basis. The analysis considers only the differences in cost between concepts, i.e., current methods vs. irradiation, and ignores costs that remain unaffected by a switch to irradiation. Cost impacts are illustrated by means of (cost), (cost difference), or ($) notations in the process flow charts.

Discussion of Alternatives

Alternative 1: Strawberries

The flow chart in Figure 1 compares the food processing steps for chilled, non-irradiated and irradiated strawberries.

Strawberries are an item with a great deal of customer appeal, but get served infrequently because of their short shelf life (mold growth can begin in 5-7 days). Strawberries also require a great deal of care in shipping because they are easily damaged and bruised.

As can be seen in the flow chart, the cost differences to be analyzed for strawberries are the cost of transport to the irradiation facility (assumed to be a freestanding facility, because it is unlikely that strawberry producers will have their own irradiation capability), and the cost of the actual radiation application. These costs are included in Table 4. The serving size is 3 ounces.

Table 4. Strawberries Cost Comparison

	Fresh Chilled Non-Irradiated ($/serving)	Fresh Chilled Irradiated ($/serving)
Supplemental Temperature Controlled Transportation	--------	$0.002
Irradiation*	--------	$0.005
Totals	--------	$0.007

*Annual volume is 25 million pounds of boxed product, free standing irradiator operating 125 days per year, three shifts per day, 2.5 kGy dose, 25% net utilization efficiency.[16]

STRAWBERRIES

INDUSTRIAL PROCESS FLOW

CURRENT	COMMON PROCESSES	IRRADIATION
	PRODUCER	
-----------		(cost) REFRIG.TRANSPORT
-----------		(cost) IRRADIATION
	REFRIG. TRANSPORT	
	WHOLESALER REFRIG. STORAGE	
	REFRIG. TRANSPORT	
	REFRIG. STORAGE	

Figure 1. Strawberry Process Flow.

The cost for irradiation of strawberries is based on Cobalt 60 as a source. At the same annual volume, the cost to irradiate using an electron accelerator machine source (4.5-million electron volt electron beams converted to X-rays) is estimated at $0.0063 per serving.

Research has shown that Cobalt 60 is less expensive than electron beams at lower dose levels for annual volumes below 50 million pounds.[17] The amount of Cobalt 60 needed is directly related to the dose required and the amount of product that must be treated during a set amount of time. As the irradiator size and/or dose increases, Cobalt 60 becomes a larger portion of total annual costs. The power requirements for an electron accelerator are also directly related to dose and hourly throughput. However, electron accelerators have an advantage in that capital requirements increase at a slower rate than capacity.

Strawberries irradiated at a free standing facility (transportation cost represents transportation from packer to the irradiation site), without considering loss due to spoilage, would cost about seven tenths of one cent more per serving (3 ounces), as compared to the chilled non-irradiated product. Strawberries are frequently attacked by the fungi Botrytis cinerea Pers. ex Fr., or "gray mold", which can extensively develop after harvest. One infected fruit can affect those around it, a phenomena known as "nesting". Consequently, one infected fruit in a container may eventually result in complete loss of a batch or container of fruits.[18] Growth of the fungus is slowed, not stopped, by refrigeration. Laboratory studies have shown that treatment of ripe strawberries with low dose irradiation can significantly

reduce the growth of "gray mold", and in turn increase shelf-life, without noticeable softening. Research has shown strawberries to have a high tolerance to radiation, as compared to other fruits.[19]

As can be seen in Table 5 and Figure 2, mold growth appears two days later in the irradiated product, and at a lower percentage.[20] The rate of mold growth is also slightly lower for the irradiated product. This effectively gives the buyer a little more shelf life, which is all that might be needed in terms of receiving the amount of non-spoiled product that is required.

However, having product that is in good enough condition to serve is not the only issue. The following formula has been used to show the effect that spoilage can have on net cost:

$$N = B/(1-SP)$$

Where:

N = Net Actual Cost
B = Base or Quoted Purchase Price
SP = Fraction Spoiled

The Defense Personnel Supply Center purchased 3,092,947 pounds of fresh strawberries in fiscal year 1990, at an average price of $1.15 per pound.[21] If eight days had elapsed by the time these strawberries actually reached a dining hall, it is possible, based on the spoilage rate data of Table 5, that 17% were mold infested. The real cost for the strawberries that could be served would be $1.39 per pound. The irradiated strawberries would cost $1.19 per pound (the $1.15 purchase price plus $0.0270/lb. for irradiation and $0.0106/lb. for supplemental transportation), for a savings of approximately 14% per pound, or $604,801. If 10 days had elapsed, the irradiated product would represent a cost savings of about 33%, or $2,222,566.

The differences in cost and shelf life can be greater over longer periods of time if strawberries packaged in 0.03 mm polyethylene film are considered (Table 6 and Figure 3). Packaging with film can greatly extend strawberry shelf-life, as opposed to loose pack, because there is less cross contamination or "nesting" between berries. The net effect on shelf life is even more dramatic after radiation has been applied: research experiments have shown the irradiated product packaged in polyethylene film can last up to 23 days without any appearance of decay, and after 26 days, only 5% show decay. The non-irradiated product would be 85% decayed after 26 days.[22]

Alternative 2: Baked Ham Slices

The fact that an irradiated ham slice product will closely resemble what the customer would get in a retail establishment is the greatest selling point for this item. Irradiated ham slices served in the field will have better taste, texture, and appearance (e.g. the coloring of a baked product as opposed

Table 5. Bulk Strawberries Cost

EFFECT OF IRRADIATION ON COST OF STRAWBERRIES (Bulk)

Day	Non Irr. % Mildewed	Non Irr. Net $	Irr. % Mildewed	Irr. Net $	$ Diff.	% Cost Diff.
7	7	1.24	0	1.19	0.05	4
8	17	1.39	0	1.19	0.20	14
9	25	1.53	7	1.28	0.25	17
10	47	2.17	18	1.45	0.72	33
11	65	3.28	28	1.65	1.63	50
12	82	6.39	39	1.95	4.44	69
13	87	8.85	48	2.28	6.57	74
14	92	14.37	57	2.77	11.60	81
15	95	23.00	63	3.22	19.78	86

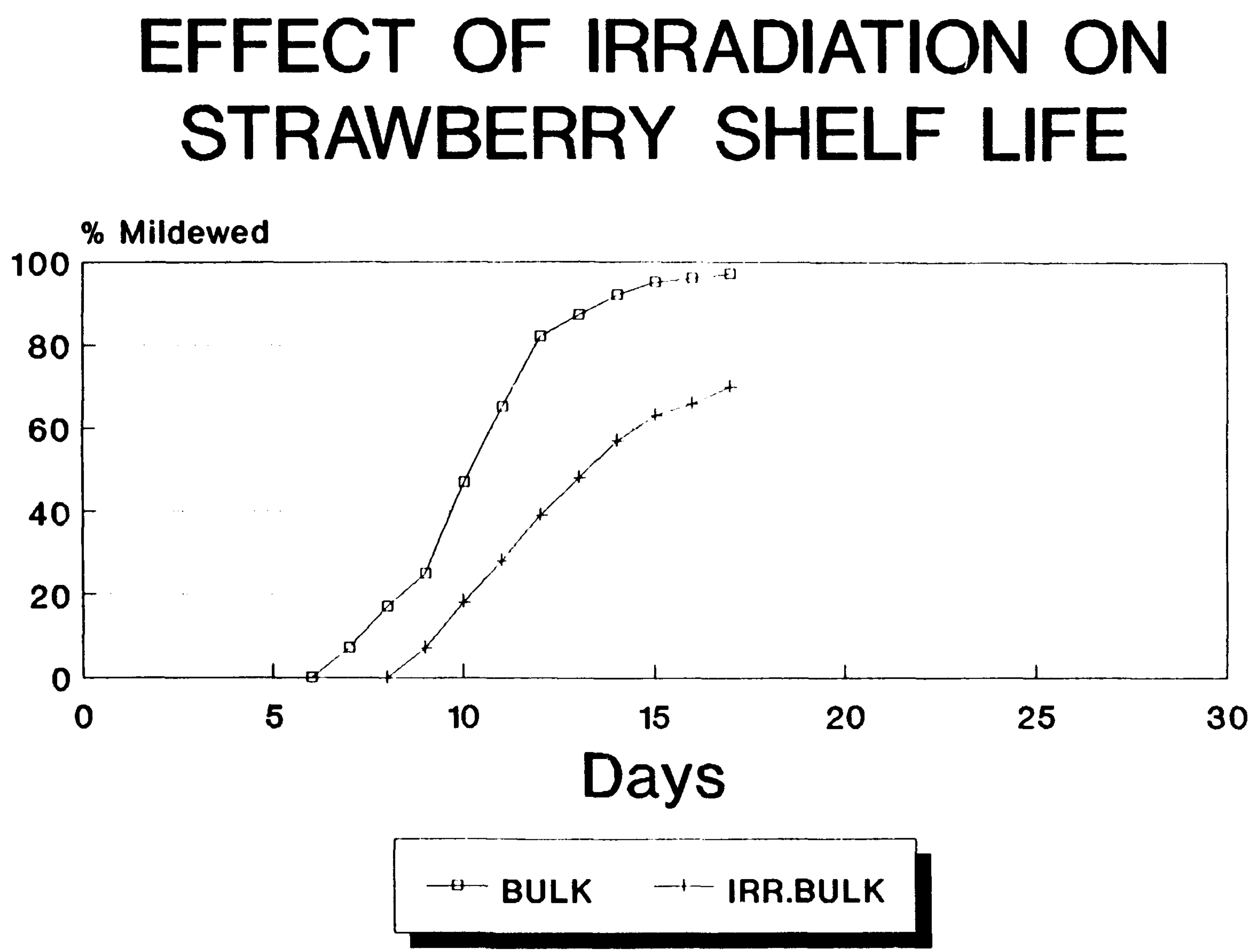

Figure 2. Bulk Strawberry Shelf Life

Table 6. Packaged Strawberries Cost

EFFECT OF IRRADIATION ON COST OF STRAWBERRIES (Packaged)

Day	Non Irr. % Mildew	Non Irr. Net $	Irr. % Mildew	Irr. Net $	$ Diff	% Cost Diff
17	8	1.25	0	1.19	0.06	5
18	14	1.34	0	1.19	0.15	11
19	22	1.47	0	1.19	0.28	19
20	33	1.72	0	1.19	0.53	31
21	47	2.25	0	1.19	1.06	47
22	62	3.02	0	1.19	1.83	61
23	76	4.79	0	1.19	3.60	75
24	78	5.23	3	1.23	4.00	76
25	79	5.48	4	1.24	4.24	77
26	85	7.67	5	1.25	6.42	84

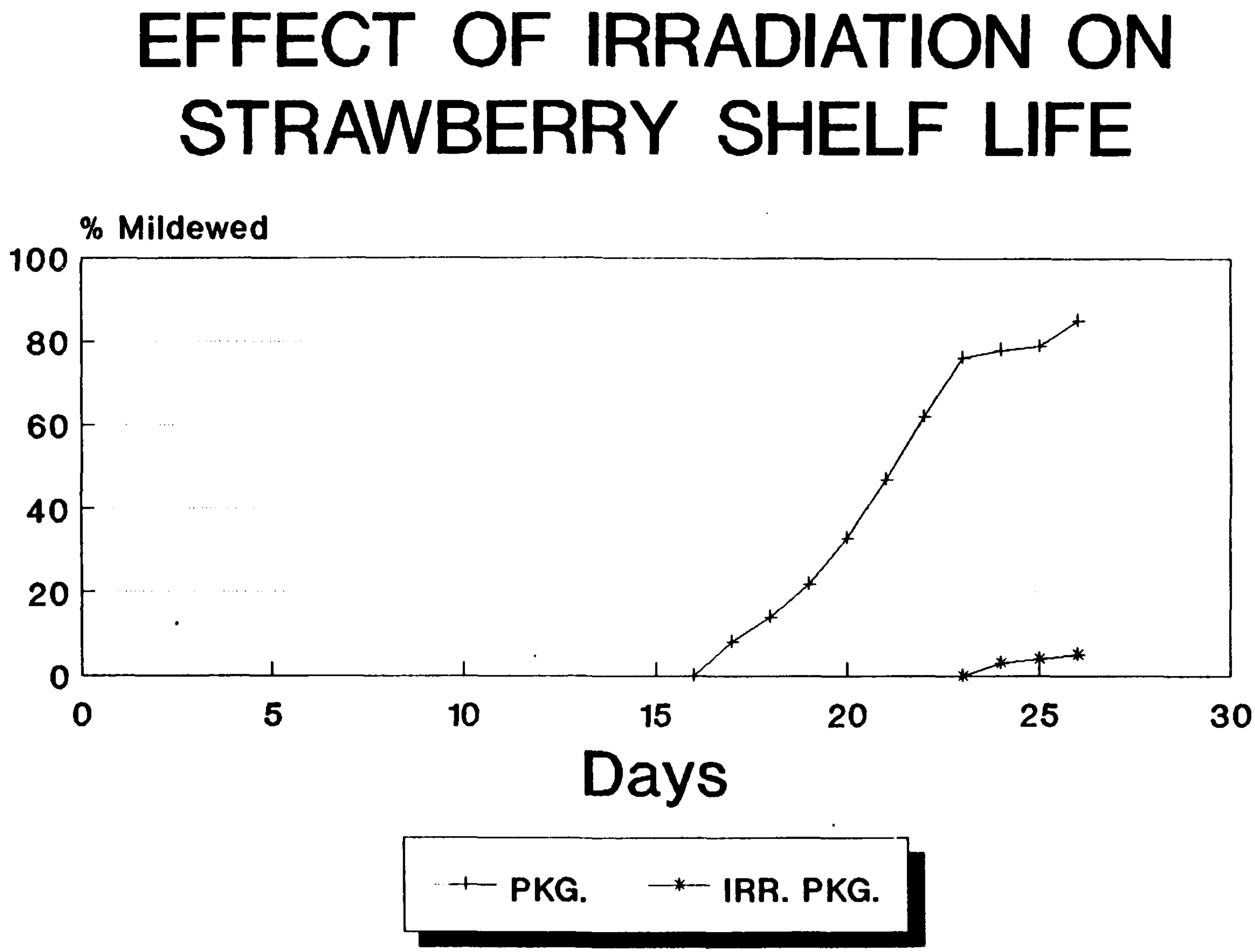

Figure 3. Packaged Strawberry Shelf Life

to the look of a boiled product). The item would not be packed in a brine medium, which is required for heat transfer to sterilize the current tray can product. The processing flow chart for the ham slices is included in Figure 5.

The irradiated product is packaged without added liquid in a vacuum sealed, flexible institutional pouch. Irradiation does not need added liquid for processing, because heat transfer is not necessary. However, adequate thermal transfer is necessary for reheating the product in the field. The vacuum processing essentially pulls the packaging material tightly around the product. This feature, along with the fact that the product will be packed in a single layer, will allow maximum heat transfer from the field feeding heat source (water immersion) to the product.

The processed portion gross weight is 5.78 ounces for the current tray can product, and 3.11 ounces for the irradiated product. The actual serving size (slightly more than 3 ounces of ham) is the same for both products. However, with the tray can item, brine is added, which makes the contents actually processed greater than the pouch product, which does not have added brine. The volume requirement of the irradiated product might be slightly less than the tray can item. However, the irradiated item has never been packaged in greater than experimental quantities, and consequently, the final package shape and size has not been determined. For the purposes of this analysis, the volume requirements are considered the same for both products. The values of pertinent cost factors for the ham slices cost comparison are presented in Table 7. Transportation (dry) costs represent a 2000-mile shipment from a vendor to a depot.

Table 7. Cost Comparison Ham Slices.

	Tray Can Retort ($/serving)	Flex. Pouch Irradiated ($/serving)
Packaging	$0.069	$0.056
Blast Freezing	-------	$0.011
Retort	$0.012	------
Irradiation*	-------	$0.010
Transportation	$0.037	$0.019
TOTALS	$0.118	$0.096

*Integrated facility, volume = 42 million lbs./yr., throughput = 7,937 lbs./hr., plant operating 5250 hrs./yr., 40 kGy dose, 10 MeV electron beams, 100kW beam power.[23]

HAM SLICES

INDUSTRIAL PROCESS FLOW

RETORTING	COMMON PROCESSES	IRRADIATION
	SLAUGHTER	
	STORAGE OF CARCASS 24-72 HOURS	
	AUTOMATIC/MANUAL BREAKDOWN	
	MIX, FORM, CURE	
	PRECOOK (enzyme inactivation)	
	COOL	
	BULK PACK	
	SLICING	
CANNING	(cost difference)	PACKAGING
------------------	(cost)	FREEZE
RETORTING	(cost difference)	IRRADIATION
	TRANSPORTATION AMBIENT (cost difference)	

Figure 5. Tray Pack Ham Slices Process Flow.

Recent purchases of tray pack ham slices totaled 5,132,160 servings at $1.25 per serving.[24] The irradiated ham slices will cost about $0.022 less per serving than the retort item, which translates into a cost savings of about $113,000 (1.8%) for the $6,461,198 order. The savings result from the lower cost of the flexible pouch package ($1.00 each) as compared to the tray can ($1.25 each), and the reduced cost for transporting flexible pouch product from the vendor to the depot. Currently, pallets of tray cans cannot be double stacked (i.e. two layers) in transit because of the weight of liquid in the product. However, the reduced weight of the irradiated product without added liquid permits double stacking of pallets in transit. Thus, the cost of transporting the flexible pouch product from vendor to depot is half of that cost for the tray can product. At the depot, ration entrees are assembled with other menu items into meal modules. Meal modules with tray can entrees can be double stacked in transit. Consequently, a change to meal modules with irradiated flexible pouch entrees would not result in a reduction in transportation costs from depot to customer.

Grilled Chicken Breast

The saying used to be "...a chicken in every pot". Today, considering the popularity of new poultry products, the updated version might be "...a grilled chicken breast on every plate". The broiled chicken sandwich has literally rejuvenated Burger King franchises in this era of continually flat sales for the oversaturated fast food market.

The goal for military feeding is to provide a highly acceptable, shelf stable chicken product, such as a whole grilled breast without sauce or gravy, which cannot now be provided by thermostabilized preservation methods. It is hoped that the customer will perceive the irradiated (sterilized) whole, grilled breast item as a product that more closely resembles a freshly prepared product, in comparison to chicken menu choices currently available in B ration and T ration settings. Current T ration (thermostabilized, flat, rectangular can) choices include Chicken Breast with Gravy, Chicken ala King, and Chicken Cacciatore. B ration (thermostabilized cylindrical can) choices prepared using canned diced chicken include Creole Chicken and Baked Chicken and Rice.

The flow chart for chicken is depicted in Figure 4. Thermostabilized, tray can chicken breast with gravy is being compared to irradiated, grilled chicken breast, vacuum packaged in a flexible pouch. The cost factors are included in Table 8. The serving portion is 4 ounces.

Recent contract purchases of tray can chicken breast totaled 2,025,000 servings, at $2.47 per serving. The cost of the irradiated product would be $0.06 less per serving, which translates into a cost savings of $121,500, or 2.4%.

Charbroiled Beefsteak

Today's dining out patrons want almost everything, from meats to trendy baby vegetables, broiled or grilled. Consumers are sold on the flavor, appearance, and nutritional benefits of this form of food preparation.

The capability to offer front line troops a steak item that has the much desired char-broiled look and flavor, without the need for gravy or sauce,

<u>CHICKEN</u>

<u>INDUSTRIAL PROCESS FLOW</u>

<u>RETORTING</u>	<u>COMMON PROCESSES</u>	<u>IRRADIATION</u>
	SLAUGHTER	
	SCALDING HOT WATER	
	DEFEATHERING	
	SINGEING	
	EVISCERATION	
	PRIMARY CHILL WATER	
	SECONDARY CHILL WATER/ICE	
	REFRIGERATED STORAGE	
PRECOOK (enzyme inactivation)		BONE REMOVAL
BONE REMOVAL		PRECOOK (enzyme inactivation)
		(cost) CHILL [25]
CANNING	(cost difference)	PACKAGING
------------------		(cost) FREEZING
RETORTING	(cost difference)	IRRADIATION
	TRANSPORTATION AMBIENT (cost difference)	

Figure 4. Chicken Flow Chart.

Table 8. Chicken Cost Comparison

	Tray Can Retort ($/serving)	Flex. Pouch Irradiated* ($/serving)
Packaging	$0.140	$0.110
Blast Freezing	--------	$0.017
Retort	$0.024	------
Irradiation	--------	$0.015
Transportation	$0.075	$0.037
TOTALS	$0.239	$0.179

*Integrated facility, volume = 42 million lbs./yr., throughput=7,937 lbs./hr., plant operating 5250 hrs./yr., 40 kGy dose, 10 MeV electron beams, 100 kW beam power.[26]

would be a significant achievement in field feeding. Irradiation can make this possible. The cost impacts are presented in Table 9. The serving portion is 5 ounces.

Table 9. Beefsteak Cost Comparison

	Tray Can Retort ($/serving)	Flex. Pouch Irradiated ($/serving)
Packaging	$0.140	$0.110
Blast Freezing	--------	$0.017
Retort	$0.024	-------
Irradiation*	--------	$0.015
Transportation	$0.075	$0.037
TOTALS	$0.239	$0.179

*Integrated facility, volume = 42 million lbs./yr., throughput=7,937 lbs./hr., plant operating 5250 hrs./yr., 40 kGy dose, 10 MeV electron beams, 100 kW beam power.[27]

There currently is not a tray can beef steak item. However, an institutional pouch pack irradiated beefsteak can potentially save over $0.06 per serving, compared to what a tray can beef steak item would cost if such an item was procured for military feeding.

Meal Ready-to-Eat Roast Beef

Most dining aficionados love a good, authentic deli sandwich. The goal is to enable troops in the field to make a sandwich (using the new shelf stable bread) with high quality, deli-style meats like roast beef. The roast beef would need to be precooked to a medium rare stage to inactivate enzymes before irradiation. As a result, the MRE product would have medium-rare color and texture, but be sterilized by the irradation. This combination of appearance and level of sterility is not possible with thermostabilization.

The cost breakdown for the irradiated product is included in Table 10. The serving portion is 8 ounces. The irradiated roast beef would cost about $0.035 more per serving (8 ounce) than a conventionally prepared retort item. There are no savings as a result of reduced packaging costs, because the packaging is the same for both items. With packages as thin as an individual serving MRE (Meal Ready-to-Eat field ration), added liquid is not necessary for heat transfer during thermostabilization The non-irradiated item would be "dry packed". Consequently, there are no reductions in packed weight to generate lower transportation costs. However, irradiation preservation has the potential to offer a roast beef product that more closely resembles a freshly prepared item than is possible with traditional thermostabilization processing methods.

Table 10. MRE Roast Beef Cost Comparison.

	MRE Retort ($/serving)	MRE Irradiated ($/serving)
Blast Freezing	------	$0.028
Retort	$0.017	------
Irradiation*	--------	$0.025
TOTALS	$0.017	$0.053

*Integrated facility, volume = 42 million lbs./yr., throughput=7,937 lbs./hr., plant operating 5250 hrs./yr., 40 kGy dose, 10 MeV electron beams, 100 kW beam power.[28]

Alternative 3

Ground Beef Patties

The Department of Defense purchased more ground beef patties (20.3 million pounds) in fiscal year 1990 than any other single beef item.[29] This item is extremely popular with military food service customers, as with their civilian counterparts.

A goal of Army field feeding is to bring products as fresh as possible to field units. Food irradiation can make it more tactically feasible to serve in the field products that more closely resemble their fresh counterparts than is currently possible.

The shelf life of nonirradiated chilled ground beef is 4-5 days. This shelf life is a great deal less than the time required for overseas shipment, which takes 20-30 days from vendor to customer. Frozen ground beef has the shelf life to survive the shipment. However, it is rare for frozen storage to be available in field situations. If field refrigerators (reefers) are available, than one could expect to get 7-10 days shelf life (3-5 days for the product to temper, 4-5 days remaining shelf life in the reefers) from frozen beef patties, once the product is off-loaded at the port of destination. This may not be enough time for the product to be shipped to, and used by, field units.

Low-dose irradiation (dose = 2.5 kGy) can extend the shelf life of fresh ground lamb from one to four weeks.[30] The composition of beef is very similar to lamb. It is expected that the shelf life of chilled beef would be extended from 4 days to 3-4 weeks if exposed to the same dose of irradiation. However, this still is not enough time for a chilled shipment to be delivered to an overseas customer before its expiration date, based on current shipping times from the United States to Europe (20-25 days) and South West Asia (25-30 days).

One option to alleviate these problems is to ship frozen beef that has been irradiated with a low dose. Once in port, it would temper (3 days) when stored under chilled conditions, and then would have a shelf life of an additional 21-28 days under chilled conditions. The irradiated hamburger patties (previously frozen) could potentially be held under refrigerated storage for a minimum of shelf life of 24 days after being off-loaded from the ship. This is six times the shelf life of non-irradiated, chilled ground beef patties, and three times the shelf life of non-irradiated frozen ground beef patties that are tempered after off-loading from the transport ship.

If chilled storage is available in the field, then the combination of frozen and irradiated (low dose) processing can provide a clear tactical advantage to field feeding situations.

If chilled storage is not available in the field, then a shelf stable irradiated (high dose) product is another option. After processing, refrigeration would not be required during storage or transportation.

The process flow for these options is included in Figure 6. The cost factors are presented in Tables 11-13.

GROUND BEEF PATTIES

INDUSTRIAL PROCESS FLOW

COMMON PROCESSES

SLAUGHTER

CHILLED STORAGE OF CARCASS

AUTOMATIC/MANUAL BREAKDOWN

TRIM/GRIND/FORM

FROZEN	CHILLED IRRAD	FROZEN IRRAD	SHELF STABLE
			PRECOOK*
			BLAST FREEZE
PACKAGE	PACKAGE	PACKAGE	PACKAGE (cost difference)
BLAST FREEZE		BLAST FREEZE	
	LOW DOSE IRRAD (cost)	LOW DOSE IRRAD. (cost)	HIGH DOSE IRRAD. (cost)
REFRIG TRANS	REFRIG TRANS	REFRIG TRANS	DRY TRANS
		(cost difference)	
FRZ. STOR.	CHILLED STOR.	CHILLED STOR.	DRY STOR.
	(cost difference)		

Figure 6. Ground Beef Patties Process Flow.

*Assumed to be offset by reduced labor required for conventional cooking.

Table 11. Ground Beef Patties Cost Comparison
Shipment to Europe

	Non-irrad. Frozen ($/serving)	Irradiated* Chilled Low Dose ($/serving)	Irradiated* Frozen Low Dose ($/serving)	Irradiated** Shelf Stable High Dose ($/serving)
Packaging	-----	-----	-----	0.0250
Blast Freeze	0.0110	-----	0.0110	0.0110
Irradiation	-----	0.0020	0.0020	0.0180
Transportation	0.0260	0.0260	0.0260	0.0120
Storage***	0.0022	0.0017	0.0017	0.0004
TOTALS	0.0392	0.0297	0.0407	0.0664

*Integrated facility, volume = 52 million lbs./yr., throughput = 9,905 lbs./hr., plant utilization = 5250 hours/yr., 2.5 kGy dose, 7 MeV electron beams, 7.8 kW.[31]

**Integrated facility, volume = 52 million lbs./yr., throughput=9905 lbs./hr., plant utilization = 5250 hrs./yr., 40 kGy dose.[32]

***Inventory Turnover 26 Times per year

Table 12. Ground Beef Patties Cost Comparison
Shipment to Middle East

	Non-irrad. Frozen ($/serving)	Irradiated Chilled Low Dose ($/serving)	Irradiated* Frozen Low Dose ($/serving)	Irradiated** Shelf Stable High Dose ($/serving)
Packaging	-----	-----	-----	0.0250
Blast Freezing	0.0110	-----	0.0110	0.0110
Irradiation	-------	0.0020	0.0020	0.0180
Transportation	0.0750	0.0750	0.0750	0.0530
Storage***	0.0022	0.0017	0.0017	0.0004
TOTALS	0.0882	0.0787	0.0897	0.1074

Table 13. Ground Beef Patties Cost Comparison
CONUS 2000 Mile Shipment

	Non-irrad. Frozen ($/svg.)	Irradiated Chilled Low Dose	Irradiated* Frozen Low Dose ($/svg.)	Irradiated** Shelf Stable High Dose ($/svg.)
Packaging	-----	-----	-----	0.0250
Blast Freezing	0.0110	-----	0.0110	0.0110
Irradiation	-------	0.0020	0.0020	0.0180
Transportation	0.0134	0.0134	0.0134	0.0128
Storage***	0.0022	0.0017	0.0017	0.0004
TOTALS	0.0266	0.0171	0.0281	0.0672

* Integrated facility, volume = 52 million lbs./yr., throughput = 9,905 lbs./hr., plant utilization = 5250 hours/yr., 2.5 kGy dose, 7 MeV electron beams, 7.8 kW.[33]

** Integrated facility, volume = 42 million lbs./yr., throughput=7,937 lbs./hr., plant utilization = 5250 hrs./yr., 40 kGy dose, 7 MeV electron beams, 100 kW beam power.[34]

*** Inventory Turnover 26 Times per year

The total cost impacts due to preservation method are summarized in Table 14. For all the shipments, the chilled, low dose irradiation product costs about $0.01 less per serving than the current non-irradiated frozen product (the Department of Defense pays on average $0.28 per hamburger serving[35]). Cost savings from not having to blast freeze, and reduced storage costs, more than offset the cost of irradiation. The frozen irradiated product that is kept chilled from port of destination to the customer will cost slightly more than the nonirradiated frozen product, although this increase is almost not measurable.

Compared to the nonirradiated frozen product, the irradiated shelf stable product costs about $0.02 more for shipments to the Middle East, $0.03 more for shipments to Europe, and $0.04 cents more per serving for domestic shipments. The difference is due to the fact that transportation costs vary depending on shipment destination (Table 15). The greatest difference in the cost of transporting a frozen or chilled product as compared to a shelf stable product is in shipments to the Middle East, followed by Europe. Chilled/frozen and ambient transportation costs within the United States differ only slightly, which is why the increased cost for irradiation and packaging of shelf stable hamburgers is greater for service in the United States.

Shelf stable products must be packaged for protection from oxygen and reentry of microorganisms The additional packaging cost for irradiated shelf stable hamburgers is based on using the same material as for MRE entrees, which has been successfully tested in food irradiation studies.[36] The approach used would be a "bag in the box." The hamburgers would be bagged and sealed in the MRE entree material, and then placed in a standard cardboard box prior to irradiation. The box would be very similar in size and shape to the current frozen hamburger case. The cost of irradiation for hamburgers is based on the use of Cobalt 60, which must be used to penetrate the full case of product.

The cost of frozen storage is 1.3 times greater than chilled storage, and about 5.5 times that of dry storage. However, savings in storage cost are small in relation to the additional costs due to irradiation.

Shelf stable hamburgers will only have to be reheated for customer service. It is possible that the resulting lower labor and energy costs will offset the increased cost of irradiation and packaging.

Table 14. Ground Beef Patties Cost Comparison
Nonirradiated vs. Irradiated Products
$/serving

	Europe	Middle East	CONUS
Frozen, Nonirradiated	-----	-----	-----
Chilled, Irradiated Low Dose	(0.0095)	(0.0095)	(0.0095)
Frozen, Irradiated Low Dose	0.0015	0.0015	0.0015
Shelf Stable, Irradiated High Dose	0.0272	0.0192	0.0406

Table 15. 40' Container Transportation Costs

	Europe	Middle East	2000 Mile CONUS Shipment
General Dry	$2467	$10,760	$2580
Refrig/Frozen	$5286	$15,120	$2700

IV. Conclusions

In Alternative 1, low dose irradiation to extend the shelf life of a chilled product was examined. It appears from the analysis of this alternative that irradiation can be of benefit in extending the shelf life of highly perishable chilled items, such as strawberries. The potential reduced losses due to spoilage of the irradiated product can have a large effect on net cost. The example provided on strawberries shows that when loss due to spoilage is taken into consideration, irradiation can generate cost savings of 14% and higher compared to the actual cost of the conventional chilled product.

A comparison of sterilization by retort (tray can) and by irradiation (flexible institutional pouch) was made in Alternative 2. For group feeding items (i.e., bulk feeding containers with low ratios of net weight to liquid content weight), the costs associated with irradiation (irradiation, blast freezing) can be offset by reduced transportation and packaging costs. The cost of transportation from vendor to depot is reduced because the pouch packaged irradiated product (with no added liquid) weighs substantially less than a thermostabilized tray can counterpart. This allows double the quantity of the irradiated product to be delivered per shipping container. In addition, the flexible institutional pouch costs 20% less than the tray can.

For individual rations (i.e., net weight to liquid weight ratio can be high), the costs associated with irradiation are additional, since weight savings are not generally possible, and there is no change in packaging from the current ration to produce cost reductions.

In Alternative 3, three options for processing ground beef patties were compared to conventional preservation by freezing: a low dose chilled product with extended shelf life; a combination of freezing and irradiation (low dose) to extend shelf life; and irradiation (high dose) sterilization to achieve shelf stability. The chilled low dose hamburger costs about $0.01 (3.6%) less than the current nonirradiated frozen product. The shelf life of 21-28 days can be taken advantage of in domestic shipments. However, the product does not provide a comfortable margin for shipment overseas, which usually requires 20-30 days.

The frozen irradiated (low dose) product can provide a clear tactical advantage in overseas field situations, but will cost slightly more (one half of one percent) than the conventional frozen item. This concept is designed to take advantage of the fact that if any temperature controlled storage is available in the field, it is usually chilled and not frozen. This irradiated product is kept frozen during overseas shipments, and is allowed to temper in field reefers after being off-loaded from cargo ships. This would provide 24-31 days shelf life after being off-loaded at the port, as compared to 7-10 days shelf life of a non-irradiated frozen product that is allowed to temper in field reefers. It normally takes 3-7 days in theater for shipment from port to customer.[37] This leaves a minimum of 17 days shelf life remaining to provide logistical flexibility in field feeding situations, provided field refrigeration is available.

The shelf stable hamburger provides a clear-cut tactical advantage in field feeding situations. From a logistic point of view, field reefers do not have be purchased, transported, leased or maintained for this item. The shelf

stable item will cost more, since savings in transportation and storage costs do not offset cost increases for packaging to maintain shelf stability and the irradiation process. The cost increase per serving for hamburgers shipped to the Middle East is $0.02, $0.03 for Europe, and $0.04 for shipments in the United States. This item would be precooked, and would only have to be reheated for customer service. Savings associated with reduced energy and labor costs at final preparation have not been factored into this analysis. It is possible that such savings will offset the increased cost attributed to attaining shelf stability.

The cost of irradiation preservation fluctuates depending on many major factors: the radiation source, the dose level, product throughput per hour, annual volume, and source efficiency. Cobalt 60 has the advantage of high penetration capability, but gets relatively expensive as dose and volume increase. The cost of Cobalt 60 becomes an increasingly larger percentage of annual operating cost as output increases. Capital requirements for electron accelerators increase at a slower rate than power capacity. This is illustrated in Table 16. Annual capital costs are presented as estimated for the radiation source, and as a percentage of total annual capital costs for the radiation facility.

Table 16. Annual Cost of Radiation Source

	Dose=2.5 kGy			Dose=40 kGy		
	Annual $(000)	% Total	Irrad. Cost/lb.	Annual $(000)	% Total	Irrad. Cost/lb.
Electron Beam*	164	27	$0.012	943	45	$0.049
Cobalt 60**	241	36	$0.013	3,771	77	$0.094

* 42 million pounds per year
** 52 million pounds per year

As volume and/or dose level increase, electron beam processing seems to have the economic advantage. However, electron beam processing has limited penetration capability, and thus cannot be used on products that are more than 1-inch thick. Generally, when the item to be irradiated is greater than a single serving, some form of irradiation other than electron beams must be used.

Foods, like other organic and inorganic items, are mixtures of different chemical compounds. The qualities we aim to influence in the kitchen, processing plant, or laboratory - taste, texture, color, quality - are all manifestations of chemical properties and chemical reactions. Food is a world of molecules and their reactions to each other and the processes they are exposed to - broiling, grilling, chilling, freezing, irradiating - that enhance the utility of food. Irradiation is another preservation method science has discovered that can help military food service produce shelf stable and extended shelf life chilled products of higher quality than now possible.

This document reports research undertaken at the US Army Natick Research, Development and Engineering Center and has been assigned No. NATICK/TR-92/006 in the series of reports approved for publication.

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25 Hamilton A. Olabode, et. al., "Total Energy to Produce Food Servings as a Function of Processing and Marketing Modes", Journal of Food Science, Vol. 42, No. 3 (1977). Article reports that chilling requires 5% of the Btu

requirements of blast freezing. The cost for this chilling operation is considered insignificant for the purposes of this study.

26 Council for Agricultural Science and Technology, Ionizing Energy in Food Processing and Pest Control: II. Applications, Task Force Report No. 115, Ames, Iowa, June 1989.

27 See #23.

28 See #23.

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32 See #23.

33 See #31.

34 See #23.

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37 Telephone conversation with Mr. Tom Strausbaugh, Military Traffic Management Command, Falls Church, VA, 1-17-91.

Appendix A
Reference Data

COST/DATA SUMMARY AND SOURCES

1. Data Summary on 40 ft. Shipping Container - used for domestic and overseas shipment of dry and refrigerated/frozen product.

a. Ft. Lee office for Direct Commissary Support System, Mr. Carl Younce, 804/734-3764, AV:687-3764, 1-18-91.

- One 40 ft. shipping container = 56 measurement tons = 2240 maximum cf (cubic feet).
(1 measurement ton = 40 cf.)

- maximum cargo weight per container = 46,000 lbs.

- average net cf of product per shipment = 1800 cf

- normally, each 40 ft. container will hold 40 total pallets:
    - -20 pallets on bottom layer (2 rows of 10 pallets each), and;
    - -20 pallets on the top layer.

b. Military Transportation Management Command (MTMC), Mr. Tom Strausbaugh, Falls Church, VA AV: 289-1577/1717, 1-17-91.

- Cost for shipment of 40 ft. container from a vendor in eastern United States to, for example, Europe or Saudi Arabia, is a flat rate charged to the shipping service (i.e., Army, Navy etc.) by the Military Sealift Command (MSC). This rate is published in the MSC Container & Rate Guide. MTMC administers shipping contracts with carriers, depending on origin, port, and destination. The additive route costs of these contracts are used to determine the flat rate charged to military customers.

- Shipping Cost East Coast to Europe = 10-15 days (port to port). General cargo = $44.05 per meas. ton = $2467 per container. Temperature Controlled Cargo (refrig. or frozen) = $94.40 per meas. ton = $5286 per container.

-Shipping Cost East Coast to the Middle East = 24-25 days (port to port). General cargo = $192.15 per meas. ton = $10760 per container. Temperature Controlled Cargo (refrig. or frozen) = $270 per meas. ton = $15120 per container.

- A domestic shipment, such as Chicago to an east coast port, usually will not take longer than 3 days.

- Once the product gets in theater, the maximum time to destination is 8 days (contract stipulated).

- Overall: East Coast to Europe = average 26 days, including domestic portion of trip; East Coast to Saudi Arabia = average 36 days.

c. Major Sherrill, Chief, Defense Subsistence Office, Bayonne, N.J. AV:247-7447, 1-22/23-91.

- 35-40 cases average per pallet. Average 40,000 lbs. net product per trailer.

- Uses a planning factor of 1250 cf net product per container.

d. Mr. Buddy Maull, Defense Personnel Support Center, Subsistence Supply Operations Division, Perishable Branch (DPSC-HOP). Administrator of the Chilled Beef to Europe program. AV: 444-4503, 1-23-91

- Average 18 pallets per layer, per 40 ft. container.

e. Military Traffic Management Command, Freight Traffic Department, Bayonne, N.J. Marge, AV: 247-7196, 1-22/23-91.

-Requested freight rates for 40 ft. container over three domestic routes: Chicago, IL - Cincinnati, OH = 285 miles; Chicago, IL - Memphis, TN = 532 miles; Chicago, IL - Peoria, IL = 153 miles. Average cost per mile for dry (non-refrigerated) shipments = \$1.29, temperature controlled shipments (refrigerated/frozen) = \$1.35. Rates include average 9% fuel surcharge.

<u>-Based on the above transportation information, the following will be assumed for 40 ft shipping containers</u>: 1. maximum usable space per container is 1525 cf (this is the average of 1800 cf per Mr. Younce, and 1250 cf per Maj. Sherrill); 2. maximum quantity of 40 pallets; 3. maximum gross cargo weight = 46,000 lbs.

2. <u>Data Summary on Storage Costs</u>

Storage cost data was obtained from local commercial sources. All storage rates are per 100 lbs/month, with the handling charge being a one-time (i.e. in and out) cost.

Atlantic Cold Storage Corp. 617/442-6722, 1-21-91
- frozen = \$.99 handling per 100 lbs, \$.71 storage per 100 lbs.
- refrigerated = \$.65 handling per 100 lbs, \$.65 storage per 100 lbs.

Americold 617/923-2100, 1-21-91
- frozen and refrigerated = \$2.04 handling, \$1.50 storage per 100 lbs.

Condyne Cold Storage 617/344-0500, 1-21-91 (Condyne has been awarded a 3 year contract with Defense Subsistence Office, Boston).
- frozen = \$1.50 handling per 100 lbs., \$1.20 storage per 100 lbs.
- refrigerated = \$1.00 handling per 100 lbs., \$1.00 storage per 100 lbs.

American Cold Storage & Warehouse Corp. 617/329-8585, 1-21-91
- frozen = $.60 handling per 100 lbs., $.60 storage per 100 lbs.
- refrigerated = $.50 handling per 100 lbs., $.50 storage per 100 lbs.
- dry = $5.00 per pallet handling, $5.00 per pallet storage

Affiliated Warehouse, Inc. 508/588-1280, 1-21-91
- dry = $7.50 per pallet handling, $7.50 per pallet storage

Wakefield Distribution, 508/777-5360, 1-21-91
- dry = $6.50 per pallet handling, $6.50 per pallet storage.

Average Storage Costs based on above data are as follows:

Dry Per Pallet/Month: handling = $6.33; storage = $6.33 ($76 annual storage cost per pallet).

Refrigeration Per 100 lbs./month: handling = $1.04; storage = $.91 (annual storage cost = $.11 per pound).

Freezer Per 100 lbs./month: handling = $1.28, storage = $1.01 (annual storage cost = $.12 per pound)

Per 1986 American Society of Heating, Refrigerating and Air Conditioning Engineers, Inc. Handbook, Inch-Pound Edition, refrigerated items average 32 lbs./cf, and frozen items average 38 lbs./cf. Given this information, and the above average refrigeration and freezer storage costs, cf costs of refrigerated and frozen storage for this analysis are established as:

refrigeration = $3.52/cf annual storage cost.
frozen = $4.56/cf annual storage cost.

3. Data Summary on Processing Costs

Processing costs were calculated based on information from a variety of sources.

Three sources in the literature were used to determine the energy requirements of blast freezing and retort processing. In the first source, Identification of Major Areas of Energy Utilization in the Food Processing/Foodservice Industry, Samuel J. Dwyer, III, University of Missouri-Columbia, MO, 1977 (funded by the National Science Foundation, grant # N F SIA 75-16222) it was determined that blast freezing diced chicken requires 1276 BTU's/lb., and retorting diced chicken required 395 BTU's/lb. The Dwyer finding for retorting was also used by Brynjolfsson in "Energy and Food Irradiation", International Atomic Energy Association publication SM-221/54, 1978. Hamilton A. Olabode, et. al. in "Total Energy to Produce Food Servings as a Function of Processing and Marketing Modes", Journal of Food Science, Vol 42, No. 3, 1977, determined energy requirements for blast freezing potatoes was 1464 BTU's/ lb.

The average cost per KWH for commercial customers in the United States for 1990 was $0.0735/KWH (National Energy Information Center, Washington D.C., 202/586-8800).

Conversion factors researched for this report are from The Statistical Abstract of the United States 1990, U.S. Department of Commerce, Section 19 Energy:

-Petroleum - 5.403 mil. Btu per barrel

-Coal - 21.517 mil Btu per short ton (2000 lbs.)=10,758 Btu's per lb. Cost of Bituminous coal is assumed to be $23/short ton.

-Fossil fuel steam-electric power plant generation factor of 10,253 Btu per KWH (heat generation only, not consumption).

The average cost of natural gas to commercial customers in the United States 11 months in 1990 was $4.96 per million BTU's. Source is the American Gas Association, Arlington, VA, 703/841-8400.

Processing Costs

Food processors contacted were recommended by food buyers at the Defense Personnel Support Center. Obtaining actual processing costs from industry contacts proved more difficult than expected. Some sources stated they did not keep detailed enough cost data to determine the cost of specific food processing operations. The information obtained is as follows:

Blast Freeze

Goldkiss Foods, Georgia, 404/393-5000: $0.035/lb., plant/equipment depreciation, labor, energy.
Tyson Foods, Arkansas, 501/756-4000: $0.070/lb., plant/equipment depreciation, labor, energy
Tip Top Poultry, Georgia, 404/973-8070: $0.055/lb., plant/equipment depreciation, labor, energy
Supreme Beef, /texas, 214/428-1761: $0.016/lb. energy cost only.

NOTE: Base on above data, an average cost of $0.055/lb. is used in this report for blast freezing.

Retorting

ConAgra (formerly Blue Star Foods), Iowa, 712/322-0203:
Recent DOD Contract, 33,600 Cans/Shift, cost per 6.5 lb. can:
Energy=$0.035
Maintenance=$0.005
Labor=$0.007
Retort Equipment depreciation=$0.047
Total=$0.095/6 lb. can = $0.015/lb. Note:costs do not including building or plant depreciation.

Vanee Foods, Illinois, 708/449-7300: no info available

Pillsbury, Minnesota, 612/665-3515: cost data tracked/varies among plants; source contacted would not provide details on plant operations.

Tony Downs Foods, St. James, MN, costs per 6.5 lb. can:
Energy (steam, water, electricity) = $0.065
Labor (canning, filling, retorting) = $ 0.065
Fixed Expense (plant & equipment depreciation) = 0.09
Total = $0.205/ 6 lb. can = $0.0328/lb.

NOTE: The data from Tony Downs Foods appears to be the most complete in terms of covering all major costs which should include: labor, energy, and fixed expense that includes cost of retort equipment and buildings/facilities. A cost of $0.033/lb is used in this report as the cost of retorting.

Operational Data on Chicken

Tray Can Nonirradiated Chicken Breast with Gravy:

can = 6.5 lbs. net weight, 2.81 lbs. drained weight.
servings/can = 9
consumable production weight/serving = 11.55 ounces = 0.7219 lb.
4 cans/case = 36 servings/case
case cf = .68, consumable serving cf = .0189
case gross weight = 33 lbs.
46000 lbs. max. wgt. per 40 ft. container = max. 1394 cases per 40 ft. container
48 cases/pallet = 1728 consumable servings/pallet
20 pallets/40 ft trailer = 34560 consumable servings/40 ft trailer
Dry trans east coast to Europe/40 ft trailer = $2467 = $.0713/svg.
Dry trans east coast to Saudi Arabia/40 ft. trailer = $10760 = 0.3113/svg.
Dry trans 1000 mile domestic shipment/40 ft. trailer = = $1290 = $0.0373/serving; 2000 mile trip = $0.0746/serving.
Annual Dry Storage Cost Per Pallet = $76 = Per Serving = $.0440

Flexible Package Institutional Pouch Irradiated Chicken Breast:

pouch = 2.81 lbs. net weight, 2.81 lbs. drained weight.
servings/pouch = 9
consumable production weight/serving = 5.0 ounces = 0.3125 lb.
4 pouches/case = 36 servings/case
pouch cf = .68, consumable serving cf = .0189
case gross weight = 15 lbs.
46000 lbs. max. wgt. per 40 ft. container = max. 3066 cases per 40 ft. container
48 cases/pallet = 1728 consumable servings/pallet
40 pallets/40 ft trailer = 69120 consumable servings/40 ft trailer
Dry trans east coast to Europe/40 ft trailer = $2467 = $.0357/svg.
Dry trans east coast to Saudi Arabia/40 ft. trailer = $10760 = $0.1557/svg.
Dry trans 1000 mile domestic shipment/40 ft. trailer = $1290 = $0.0187/serving; 2000 mile trip = $0.0374/serving.
Temp. control supplemental transportation cost = $1.35/mile; 150 mile trip = $202 = $.0029/serving.
Annual Dry Storage Cost Per Pallet = $76, Per Serving = $.0440.

Operational Data on Ground Beef Patties

Nonirradiated, Frozen, Ground Beef Patties:

NSN 8905-00-935-3268
case = 36 lbs net weight
servings/case = 192
consumable production weight/serving = 3.0 ounces = 0.1875 lb
case cf = 2.36, consumable serving cf = .0123
case gross weight = 42 lbs.
46000 lbs. max. wgt. per 40 ft. container = max. 1095 cases per 40 ft. container
35 cases/pallet, 6720 consumable servings/pallet
30 pallets/40 ft trailer, 201600 consumable servings/40 ft trailer
$2467 dry trans east coast to Europe/40 ft trailer = $.0120/svg.
$10760 dry trans east coast to Saudi Arabia/40 ft. trailer = $0.053/svg.
Dry trans 1000 mile domestic shipment/40 ft. trailer = $1290 = $0.0063/serving; 2000 mile trip = $0.0128/serving.
$5268 chilled trans east coast to Europe/40 ft trailer = $0.0260/svg.
$15120 chilled trans east coast to Saudi Arabia/40 ft. trailer = $0.0750/svg.
Chilled trans 1000 mile domestic shipment/40 ft. trailer = $1350 = $0.0067/serving; 2000 mile trip = $0.0134/serving.
Annual Frozen Storage Cost = $4.56 cf = $0.056/serving
Annual Chilled Storage Cost = $3.52 cf = $0.044/serving

Irradiated, Ground Beef Patties:

case = 36 lbs net weight
servings/case = 192
consumable production weight/serving = 3.0 ounces = 0.1875 lb
case cf = 2.36, consumable serving cf = .0123
case gross weight = 42 lbs.
35 cases/pallet, 6720 consumable servings/pallet
30 pallets/40 ft trailer, 201600 consumable servings/40 ft trailer
$2467 dry trans east coast to Europe/40 ft trailer = $.0120/svg.
$10760 dry trans east coast to Saudi Arabia/40 ft. trailer = $0.053/svg.
Dry trans 1000 mile domestic shipment/40 ft. trailer = $1290 = $0.0063/serving; 2000 mile trip = $0.0128/serving.
$5268 chilled trans east coast to Europe/40 ft trailer = $0.0260/svg.
$15120 chilled trans east coast to Saudi Arabia/40 ft. trailer = $0.0750/svg.
Chilled trans 1000 mile domestic shipment/40 ft. trailer = $1350 = $0.0067/serving; 2000 mile trip = $0.0134/serving.
Annual Frozen Storage Cost = $4.56 cf = $0.056/serving
Annual Chilled Storage Cost = $3.52 cf = $0.044/serving
Annual Dry Storage Cost = $76 per pallet = $0.011/serving
1.35/mile temp. control supplemental transportation cost, 150 mile trip = $202 = $.001/serving
MRE Packaging material costs $0.003 per square inch. Estimate for MRE material to package 1 case of shelf stable hamburgers = 1578 square inches = $4.73/case = $0.025/serving.

Operational Data - Strawberries

Per Major Sherrill, Chief, Defense Subsistence Center, Bayonne, NJ
A247-7447, 1-22-91

1 pint yields 5 servings
12 pints per flat = 60 servings/flat
cost per flat = $14
8 flats per pallet tier = 480 servings/tier
13 tiers per pallet. Pallets cannot be stacked.
Flat = 13 lbs gross weight, 12 lbs. net.
Pallet = 104 flats = 6240 servings
Per 40 ft container = 20 pallets = 124,800 servings/40' container
$1.35/mile temperature controlled supplemental transportation cost; 150 mile trip = $202 = $.002/serving.

Operational Data on Ham Slices

Nonirradiated, Tray Can Ham Slices:

can = 6.5 lbs. net weight; drained weight = 3.5 lbs.
servings/can = 18
consumable production weight/serving = 5.78 ounces = 0.3611 lb.
4 cans/case = 72 servings/case
case cf = 0.68, consumable serving cf = .0094
48 cases/pallet, 3456 consumable servings/pallet
Case gross weight = 33 lbs.
46000 lbs. max. wgt. per 40 ft. container = max. 1393 cases per 40 ft. container (pallets cannot be stacked in transit)
20 pallets/40 ft. trailer = 69120 consumable servings/40 ft. trailer
$2467 dry trans east coast to Europe/40 ft trailer = $.0357/svg.
$10760 dry trans east coast to Saudi Arabia/40 ft. trailer = $0.1557/svg.
Dry trans 1000 mile domestic shipment/40 ft. trailer = $1290 = $0.0187/serving; 2000 mile trip = $0.0374/serving.
$1.35/mile temp. control supplemental transportation cost, 150 mile trip = $202 = $.0029/svg.
Annual Dry Storage Cost Per Pallet = $76 = $.0220/svg.

Irradiated, Flexible Pouch Ham Slices:

pouch = 3.5 lbs net weight
servings/can = 18
consumable production weight/serving = 3.11 ounces = 0.1944 lbs.
4 cans/case = 72 servings/case
case cf = 0.68, consumable serving cf = .0094
48 cases/pallet, 3456 consumable servings/pallet
Case gross weight = 18 lbs.
46000 lbs. max. wgt. per 40 ft. container = max. 2555 cases per 40 ft. container (pallets cannot be stacked in transit)
40 pallets/40 ft. trailer = 138240 consumable servings/40 ft. trailer
$2467 dry trans east coast to Europe/40 ft trailer = $.0179/svg.
$10760 dry trans east coast to Saudi Arabia/40 ft. trailer = $0.0779/svg.
Dry trans 1000 mile domestic shipment/40 ft. trailer = $1290 = $0.0093/serving; 2000 mile trip = $0.0186/serving.
Annual Dry Storage Cost Per Pallet = $76 = $.0220/svg.

Operational Data Beefsteak

Nonirradiated Tray Can Beefsteak with Gravy - this is not currently an item in the tray can menu; the following theoretical data is for the purposes of cost comparison.

tray can = 6.625 lbs. net weight
servings/can = 9
consumable production weight/serving = 11.78 ounces = 0.7361 lb.
4 cans/case = 36 servings/case
case cf = .68, consumable serving cf = .0189
case gross weight = 33.5 lbs.
46000 lbs. max. wgt. per 40 ft. container = max. 1373 cases per 40 ft. container
48 cases/pallet = 1728 consumable servings/pallet
20 pallets/40 ft trailer = 34560 consumable servings/40 ft trailer
$2467 dry trans east coast to Europe/40 ft trailer = $.0713/svg.
$10760 dry trans east coast to Saudi Arabia/40 ft. trailer = 0.3113/svg.
Dry trans 1000 mile domestic shipment/40 ft. trailer = $1290 = $0.0373/serving; 2000 mile trip = $0.0746/serving.
Annual Dry Storage Cost Per Pallet = $76 = $.0440/serving.

Irradiated Flexible Pouch Beefsteak

pouch = 2.81 lbs. net weight
servings/pouch = 9
consumable production weight/serving = 5.0 ounces = 0.3125 lb.
4 pouches/case = 36 servings/case
pouch cf = .68, consumable serving cf = .0189
case gross weight = 15.16 lbs.
46000 lbs. max. wgt. per 40 ft. container = max. 3034 cases per 40 ft. container
48 cases/pallet = 1728 consumable servings/pallet
40 pallets/40 ft trailer = 69120 consumable servings/40 ft trailer
$2467 dry trans east coast to Europe/40 ft trailer = $.0357/svg.
$10760 dry trans east coast to Saudi Arabia/40 ft. trailer = $0.1557/svg.
Dry trans 1000 mile domestic shipment/40 ft. trailer = $1290 = $0.0187/serving; 2000 mile trip = $0.0374/serving.
$1.35/mile temp. control supplemental transportation cost, 150 mile trip = $202 = $.0029/serving.
Annual Dry Storage Cost Per Pallet = $76 = $.0440/svg.

Operational Data on MRE Corned Beef

There is no nonirradiated counterpart.

Irradiated MRE Corned Beef:

Each Pouch contains one 8 ounce serving.
consumable serving cf = 0.0139
46000 lbs. max. wgt. per 40 ft. container = approximately 92000 servings per 40 ft. container.
$1.35/mile temp. control supplemental transportation cost, 150 mile trip = $202 = $.0022/serving.

Packaging Information:

The Institutional Flexible Pouch weighs 0.08 lbs. empty (1.3 ounces). Pouch cf = 0.138 (10"x12"x2") when filled with product, which is about the same as the standard tray can. The empty tray can weighs about 13.6 ounces; the packing box weighs approx. 3.6 lbs empty. The packing box with 4 empty cans = 7 lbs. The packing box with 4 empty pouches = 3.92 lbs. The tray can costs $1.25; the pouch costs $1.00. Flexible pouch pallets can be stacked in transit. Tray can pallets cannot be stacked in transit. Consequently, savings from stacking pallets of institutional flexible pouches can be expected from vendor to depot. However, meal modules with tray cans can be stacked in transit. Thus, a switch to pouches in meal modules will not result in lower transportation costs from the depot to the customer, as compared to meal modules with tray cans.

The B-Ration 29 ounce (401x411) can costs $0.405 (DPSC-ANC 312/399-3000).

Ham Slices = 54 slices per tray can (3 per svg.) = 18 servings per can. One can per module. Total cooked drained weight per can is 56 ounces.

Chicken Breast with Gravy: Specified 4 ounce breast. There are 18 whole breasts per can = 9 servings. Total cooked drained weight per can = 45 ounces.

Appendix B

Irradiation Costs

Cost of Irradiation ($000's)*

	40kGy Cobalt(1)	40kGy Elec. Beam(1)
Investment Items:		
Initial Cobalt 60	18185	-
Accelerator	-	9800
Biological shielding	650	600
Irradiator machinery	325	-
Auxiliary systems	50	-
Machine room	-	25
Conveyor system	-	250
Air handling system	-	20
Control room/lab	17	17
Forklifts/palletizers	-	-
Refrigerated warehouse	-	-
Additional rooms	-	-
Design & engineering	104	90
Land -	-	120
Working capital	97	199
Total Initial Investment	19428	11001
Annualized Fixed Costs:		
Cobalt initial loading	1751	-
Cobalt replenishment	2020	-
Accelerator	-	943
Building & shielding	55	52
Machinery	49	34
Land -	-	6
Working capital	5	4
Fixed maintenance	101	168
Insurance & taxes	386	220
Plant manager	7	7
Radiation safety officer	39	39
Maintenance	8	15
Clerical	9	9
Total Annual Fixed Costs	4493	1473
Annual Variable Costs:		
Plant operators	101	101
Product handlers	-	-
Supplies	35	-
Utilities		
Machine	-	154
General	68	44
Variable Maintenance	187	312
Total Annual Variable Costs	391	611
Total Annual Costs	4884(1)	2084(1)

(1) Integrated facility, 5 days/week: 25% efficiency for Cobalt 60 (52 million pounds/year, throughput/hr. = 9905 lbs., operating 5250 hrs/year.); 40% efficiency for accelerator (42 million pounds/year, throughput/hr. = 8000 lbs., operating 5250 hrs/year). Cost calculations based on data obtained from:

Rosanna M. Morrison, <u>An Economic Analysis of Electron Accelerators and Cobalt-60 for Irradiating Food.</u> Commodity Economics Division, Economic Research Division, U.S. Department of Agriculture. Technical Bulletin No. 1762. Calculated Annual Cost for Cobalt 60 - 1.0 kGy = $545,000; 2.0 kGy = $632,000. Electron beam 1.0 kGy = $835,000; 2.0 kGy = $847,500